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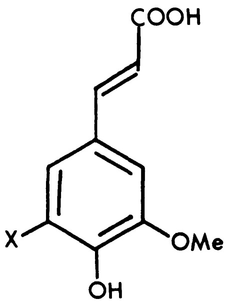
# ANODIC OXIDATION OF 4-HYDROXYCINNAMIC ACIDS

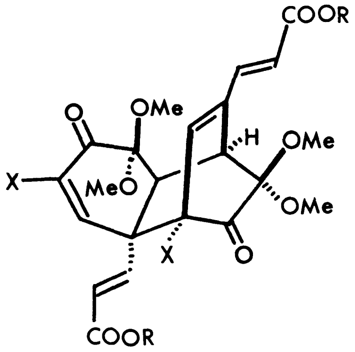
Masanobu IGUCHI, Atsuko NISHIYAMA, Hideo ETO, Yukimasa TERADA, and Shosuke YAMAMURA*
Faculty of Pharmacy, Meijo University, Tenpaku-ku, Nagoya 468

Anodic oxidation of 4-hydroxycinnamic acids was carried out at a controlled potential _vs_. SCE (+900 or 840 mV), using an undivided cell, to afford the corresponding asatone or isoasatone-type compound as well as pinoresinol-type dilactones. In these oxidation reactions, relative ratio of the two dimerization products remarkably depends on the starting acids concentration.

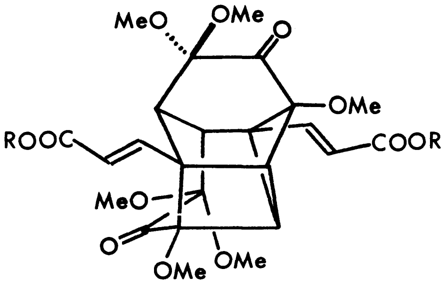
In connection with our interests in the asatone-type neolignans[1] as well as in the plant germination inhibitors[2] which are attracting increasing attention, anodic oxidation of 4-hydroxycinnamic acids (1 and 2) has been carried out.



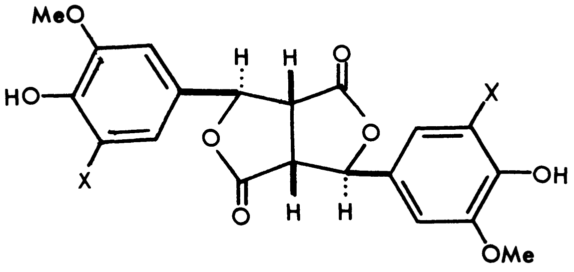
1 X = H
2 X = OMe



3 X = H, R = H
5 X = H, R = Me
9 X = OMe, R = H



6 R = H
8 R = Me

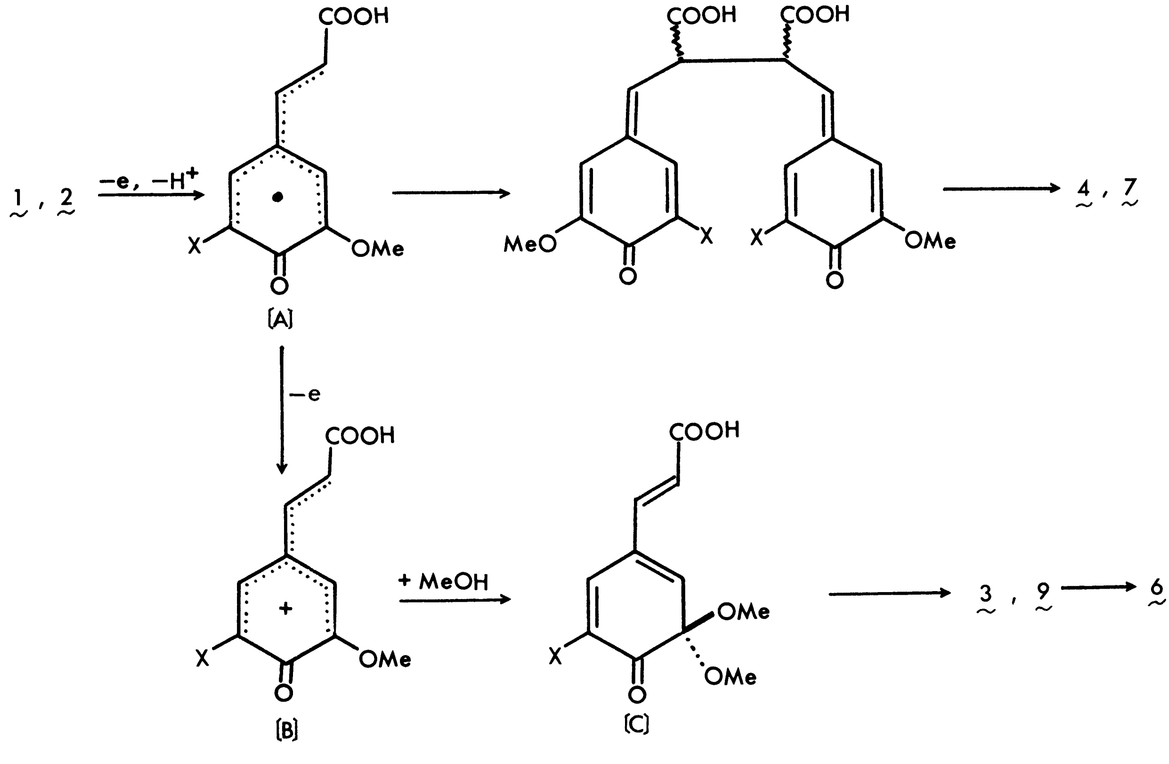


4 X = H
7 X = OMe

A 200 ml glassy carbon (GC-20) beaker and a GC rod were used as an anode and a cathode, respectively, without separation. A solution of ferulic acid (1) (10 mmol/l) in MeOH containing $LiClO_4$ (2 mol/l) as a supporting salt, was electrolyzed at room temperature for 1 h at a controlled potential of +900 mV vs. SCE.[3] The reaction solution was concentrated under reduced pressure below 40 °C, and then the residue was separated by column chromatography [LiChroprep RP-18, MeOH - $H_2O$ (1 : 1)] followed by preparative TLC [Kieselgel $PF_{254}$, hexane - EtOAc (1 : 4)] mainly to give two types of dimers (3 and 4) in 70 and 6% yields, respectively. At a low concentration of 1 (1 mmol/l), however, only the asatone-type compound (3) was produced from 1, as judged from HPLC.

Of these two oxidation products, the dilactone (4) has also been produced from 1 using $FeCl_3$ - $O_2$,[4] from which many lignans have been derived.[4,5] The remaining one can be regarded as the asatone-type compound (3) on the basis of the physical data of 3 as well as of its dimethyl ester (5)[6] [3: mp 200 °C (dec); $C_{22}H_{24}O_{10}$; $\nu_{max}$(KBr) 3200-2500, 1720br., 1710br., and 1635 $cm^{-1}$; $\delta$($CDCl_3$) 3.04(3H, s), 3.24(3H, s), 3.45(6H, s), 3.24-3.45(3H, superimposed on MeO signals), 5.99(1H, d, J= 16Hz), 6.03(1H, d, J= 10Hz), 6.06(1H, d, J= 16Hz), 6.32(1H, br.d, J= 7Hz), 6.44(1H, d, J= 10Hz), 6.94(1H, d, J= 16Hz), and 7.18(1H, d, J= 16Hz). 5 as a colorless solid: $C_{24}H_{28}O_{10}$; m/e 476($M^+$) and 238($M^+/2$); $\nu_{max}$(KBr) 1720br. and 1640 $cm^{-1}$; $\delta$($CDCl_3$) 3.05(3H, s), 3.23(3H, s), 3.45(6H, s), 3.2-3.45(3H, superimposed on MeO signals), 3.74(3H, s), 3.76(3H, s), 5.94-6.26(5H, complex), 7.00(1H, d, J= 16Hz), and 7.24(1H, d, J= 16Hz)].[7]

Scheme 1. Anodic oxidation of 4-hydroxycinnamic acids (1 and 2).



As shown in Scheme 1, the radical [A] initially formed is further oxidized, in competition with the radical dimerization leading to the formation of 4, to give the cation [B], from which the dienone [C] must be produced. Then, further dimerization of [C] may afford the asatone-type compound (3).[8]

We further carried out anodic oxidation of sinapic acid (2) under essentially the same conditions as those of 1 except for a controlled potential of +840 mV vs. SCE[3] (room temp., 1 h) to afford the corresponding isoasatone-type compound (6) and the known dilactone (7)[4] in 9 and 60% yields, respectively. At a low concentration of 2 (1 mmol/l), only the former was obtained, as seen in the case of 1. The structure of this dimer (6) was also based on the spectral data of 6 and its dimethyl ester (8)[6,9] [6: mp 200 °C (dec); $C_{24}H_{28}O_{12}$; $\nu_{max}$(KBr) 3200-2500, 1750, 1720, 1710, and 1640 cm$^{-1}$; $\delta$(DMSO-$d_6$) 3.02(6H, s), 3.16(2H, s), 3.36(6H, s), 3.47(8H, br.s), 5.90(2H, d, J= 16Hz), and 6.88(2H, br.d, J= 16Hz). 8 as a colorless solid: $C_{26}H_{32}O_{12}$; m/e 536($M^+$) and 268($M^+/2$); $\nu_{max}$(KBr) 1750, 1720br., and 1640 cm$^{-1}$; $\delta$($CDCl_3$) 3.13(6H, s), 3.30(2H, s), 3.46(6H, s), 3.56(6H, s), 3.75(6H, s), 3.84(2H, br.), 5.98(2H, d, J= 16Hz), and 7.03(2H, br.d, J= 16Hz)]. Interestingly, this dimer (6) may be produced from 2 through the corresponding asatone-type compound (9).[10]

In the present experiments, it should be noted that the asatone or isoasatone-type dimer (3 or 6) has been synthesized from the corresponding 4-hydroxycinnamic acids (1 and 2) in high yield, in contrast to E and Z-isoeugenol, the anodic oxidation of which has afforded several types of dimers.[11]

## References and Notes

1. S. Yamamura, Y. Terada, Y. Chen, M. Hong, H. Hsu, K. Sasaki, and Y. Hirata, Bull. Chem. Soc. Jpn., 49, 1940 (1976); Y. Terada and S. Yamamura, Chem. Lett., 1978, 553.
2. D. Gross, Phytochemistry, 14, 2105 (1975); G. F. Van Sumere, J. Cottenie, J. de Greef, and Kint, Recent Adv. Phytochemistry, 4, 165 (1972); D. Lavie, E. C. Levy, A. Cohen, M. Evenari, and Y. Gutterman, Nature, 249, 388 (1974); R. Cooper, E. C. Levy, and D. Lavie, J. C. S. Chem. Comm., 1977, 794 and references cited therein.
3. The controlled potential of each sample was decided on the basis of their cyclic voltamograms.
4. N. J. Cartwright and R. D. Haworth, J. Chem. Soc., 1944, 535; K. Freudenberg and H. Schraube, Chem. Ber., 88, 16 (1955); R. Ahmed, M. Lehrer, and R. Stevenson, Tetrahedron, 29, 3753 (1973) and references cited therein.
5. A. Peter, R. S. Ward, D. J. Watson, P. Collins, and I. T. Kay, Tetrahedron Lett., 1979, 2275.
6. The dimethyl esters (5 and 8) were obtained from the corresponding dimers (3 and 6), respectively, on treatment with $CH_2N_2$ in ether containing small amount of MeOH.
7. As seen in the case of demethoxyasatone, this compound (3) must have the same carbon skeleton as that of asatone. In fact, the dimethyl ester (5) was subjected to photochemical reaction using

pyrex filter to give the corresponding isoasatone-type compound (mp 191-192 °C; $C_{24}H_{28}O_{10}$), which has the same symmetric character as those of isoasatone and demethoxyisoasatone, as judged from its NMR spectrum: $\delta$($CDCl_3$) 2.88(2H, s), 3.07(2H, br.d, J= 4.5Hz), 3.24(6H, s), 3.00 (2H, br.d, J= 4.5Hz), 3.39(6H, s), 3.77(6H, s), 5.76(2H, d, J= 16Hz), and 7.11(2H, d, J= 16Hz) [M. Iguchi, A. Nishiyama, Y. Terada, and S. Yamamura, Chem. Lett., **1978**, 451].

8. In the course of separation of the reaction mixture, a possibility can not be ruled out, in which the dimeric compound (**3**) may be produced.
9. The dimethyl ester (**8**) was also produced from sinapic acid methyl ester under the similar condition as that of sinapic acid (**2**). The spectral data of **6** and **8** are quite similar to those of isoasatone[1] except for the side chains.
10. It is not clear whether the isoasatone-type compound (**6**) is formed from the asatone-type one (**9**) according to an ionic or radical mechanism.
11. M. Iguchi, A. Nishiyama, Y. Terada, and S. Yamamura, Chem. Lett., **1978**, 1015; in these cases, many arylpropanoids, licarin, guaiacin, and austrobailignan-type compounds were synthesized.

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